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Perceived Satisfaction and Development of Research Competencies in Engineering Students: A Longitudinal Study

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Abstract. This study examined changes in engineering students perceived academic satisfaction and research-related competencies between Research Workshop I and Research Workshop II, as well as the associations between perceived competencies and satisfaction at the end of the second course. A non-experimental longitudinal design was used with 66 students from Industrial Engineering and Business Management Engineering programs. Data were analyzed using the Wilcoxon signed-rank test and Spearman's rho. Academic satisfaction increased significantly across all three indicators. In contrast, changes in perceived competencies were limited to two items related to process and project management and management systems, while one operations and logistics item showed a borderline result. At the end of Research Workshop II, satisfaction was positively associated with perceived competencies in technological innovation, leadership, adaptability, and operations and logistics. These findings indicate selective changes and associations but do not support causal conclusions or uniform competency development.

Keywords: Research competencies; student satisfaction; engineering education; correlation.

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1 Introduction

Currently, equipping engineering students with research skills has become an essential priority. The ability to formulate relevant questions, search for evidence, and critically analyze it not only strengthens their academic training but also contributes to problem solving in different contexts (Monge et al., 2022; Rodriguez-Vargas et al., 2020). From this perspective, Comisión Internacional sobre los Futuros de la Educación, [CIFE] (2022) recognizes the value of science as a common good and argues that universities are responsible for promoting critical thinking, knowledge, and applied research as fundamental elements for students' comprehensive development and for the progress of societies.

Nevertheless, several studies state that the development of competencies related to research processes represents one of the main challenges for universities in Latin America and depends on the research practices implemented and the methodological support provided to students (Monge et al., 2022). This highlights the need for institutions to prioritize the development of research competencies within their educational programs (Guerra Ayala et al., 2023).

In Mexico, the valorization of research is limited by the country's economic and political conditions, administrators without an appropriate professional profile, limited resources, institutional regulations that constrain business linkage, and the lack of a culture of research commercialization among researchers (Maldonado, 2023). These conditions hinder the consolidation of effective linkages with the business sector, government, and society. In PISA 2022, Mexico reached 410 points in science, below the OECD average of 485 points; additionally, only approximately 49% of Mexican students reached the basic level of scientific competence, compared with nearly 76% observed on average across OECD member countries. These results reveal a structural tension between national scientific production and school-based scientific education. Although Mexico maintains a visible presence in international scientific indexing systems, its performance in PISA 2022 shows significant gaps in science (OECD, 2023).

On the other hand, Gonzalez et al. (2020) describe the latent conflicts associated with the proposal and publication of a new science and technology law, a set of changes involving higher education in Mexico and, consequently, its students. Therefore, the development of young researchers in Mexico becomes more complex when lower financial resources are allocated compared with the average of other Latin American countries (Rodriguez et al., 2021). The lengthy processes involved in obtaining scholarships for the development of applied research define the path and, in many cases, the future of students interested in conducting research with an impact on their immediate environment. With the transformation of the National Council of Humanities, Sciences, and Technologies (Conahcyt) into the Secretariat of Science, Humanities, Technology, and Innovation (SeCiHTi), the aim is to strengthen the linkage among educational institutions, government, and international organizations in order to promote young people's participation in research, align with the new Sustainable Development Goals (SDGs), and improve Mexico's position in the Global Innovation Index (Munoz, 2024). In addition, since its foundation in 1950, the National Association of Universities and Higher Education Institutions has brought together Mexico's main higher education institutions with the purpose of promoting their comprehensive improvement in teaching, research, cultural extension, and services (ANUIES, 2023).

Across all programs and campuses of the Tecnologico Nacional de Mexico, the courses Research Fundamentals, Research Workshop I, and Research Workshop II are offered; these courses contribute to the development of students' basic research competencies. It is important to assess these competencies and analyze students’ perceptions of their development (Moneva, 2020), since several studies show that greater self-confidence is positively associated with successful task execution and with becoming well-prepared professionals in the future (Liang et al., 2023). However, evidence regarding students’ perceptions of the research competencies developed through these courses in engineering programs at public technological institutions in Latin America remains limited.

The purpose of this study is to evaluate engineering students' perceptions regarding the development of research and disciplinary competencies during their academic training at TecNM Campus Pachuca. Specifically, the study measures the satisfaction expressed by students when participating in activities related to the development of research projects and in opportunities to participate as speakers in research seminars, colloquia, and other academic spaces aimed at strengthening their scientific training.

This article presents the following contributions:

An alternative approach to identifying students' perceived satisfaction with the development of academic research activities in engineering programs and to comparing perceived changes in competency acquisition as students progress from Research Workshop I to Research Workshop II.

An analysis of the relationship between students perceived academic satisfaction and the perceived development of their disciplinary and research competencies.

The study provides useful evidence for identifying uneven patterns in the perceived development of research competencies and guiding targeted pedagogical and curricular improvements in the Industrial Engineering and Business Management Engineering programs at TecNM Campus Pachuca.

2. Preliminaries

Previous studies on the development of research competencies in higher education differ in their design, population, and measurement approach. Kaur et al. (2023) conducted a longitudinal study with medical students at the University of Sydney, Australia, aimed at examining their perceptions while participating in research projects. The follow-up showed progress in methodological design and data analysis. Although the design made it possible to observe changes throughout the educational process, the competencies were assessed primarily through participants’ self-reported perceptions, and no comparison group was reported.

In contrast, Liang et al. (2023) employed a cross-sectional design to assess self-perceived research competencies among students at a public university in the Midwestern United States. The analysis was based on a single measurement and focused on skills such as information literacy, ethical principles, and communication. Unlike the longitudinal study by Kaur et al. (2023), this study did not examine the development of competencies at different points in time or determine changes associated with a specific educational experience.

In Mexico, Corona et al. (2024) combined a questionnaire administered to 151 undergraduate and graduate students with a qualitative evaluation of 26 participants upon completion of a research course, followed by an assessment conducted one year later. The sample consisted mainly of students from Psychology and International Relations. This design included more than one observation point and made it possible to explore the retention of learning over time; however, the follow-up was conducted only with a subsample and did not include a comparison group. The findings were based primarily on participants’ self-reported assessments.

From an institutional perspective, Maldonado (2023) proposed a model to characterize the valorization of research in Mexican higher education institutions, based on the experience of organizations located in Tamaulipas. Unlike studies focused on students, this work adopted an exploratory and contextual approach aimed at analyzing the institutional conditions that facilitate or constrain the generation and application of knowledge. Therefore, its unit of analysis, objectives, and evidence are not directly comparable with studies that assess individual competencies.

Taken together, these studies reveal a predominance of self-reported measures, samples concentrated in specific disciplines, and designs without comparison groups. They also highlight the limited availability of longitudinal studies that assess the same students at different stages of their education and examine both changes in perceived competencies and their relationship with academic satisfaction. This need is particularly relevant because research and transversal competencies do not always develop automatically through research courses, owing to their fragmented integration and limited alignment with established curricula (Valderrama et al., 2022). Therefore, longitudinal studies involving engineering students that incorporate repeated measurements and analyses for paired samples are warranted.

3. Methodology

This study adopted a descriptive quantitative approach with a non-experimental longitudinal design (Hernández & Mendoza, 2023), as the variables were observed without deliberate manipulation and analyzed at different time points using the same participants. The study variables are presented in Table 1.

Table 1. Identification of the study variables.

Variable	Dimension	Item
Competencies Generics	Teamwork	4, 5, 6, 7, 8
	Effective communication	9, 10, 11, 12, 13
	Adaptability	14, 15, 16, 17
	Leadership	18, 19, 20, 21, 22
Competencies Disciplinaries	Productivity management and improvement	23, 24, 25
	Operations management and logistics	26, 27, 28, 29
	Process and project management	30, 31, 32, 33
	Quality, environmental or safety management systems	34, 35, 36, 37, 38
	Technological innovation	39, 40, 41
Variable		
Satisfaction		42, 43, 44

Before its initial administration, the instrument was pilot tested with 20 students: 14 from the Industrial Engineering program and six from the Business Management Engineering program. Participants were randomly selected from among the students enrolled in Research Workshop II during the week of November 18–22, 2024, and were not included in the longitudinal study.

The instrument was developed by adapting constructs and items from the questionnaire by Güilamo (2014), the follow-up survey of graduates from the Technological Institute of San Luis Potosí (2021), and the questionnaire for graduates and employers from the Autonomous University of the State of Hidalgo (2025). Adjustments derived from the pilot test were also incorporated. The final version consists of 44 items corresponding to the variables that constitute the generic and disciplinary competencies analyzed, three items related to satisfaction, and three student identification items that were not included in the study. The items were scored on a five-point Likert scale, from “strongly agree” (5) to “strongly disagree” (1) and were administered using Google Forms.

Content validity was assessed by four faculty members with experience teaching Research Workshop I and Research Workshop II in the Industrial Engineering and Business Management Engineering programs at TecNM Campus Pachuca during both semesters of 2024. The experts examined the relevance, clarity, and coherence of the items, as well as their correspondence with the proposed dimensions. The internal consistency of the instrument was determined using Cronbach's alpha coefficient with 20 students from the pilot test, which reached a value of 0.98, calculated with SPSS version 23.

A census approach was used. All 66 students enrolled in Research Workshop I during the January–June 2025 semester in the Industrial Engineering and Business Management Engineering programs. The same students were subsequently assessed while enrolled in Research Workshop II during the August–December 2025 semester. Twenty-three students enrolled in Research Workshop II who had not completed Research Workshop I in the immediately preceding semester were excluded because they did not meet the longitudinal follow-up criterion. Before data collection, participants were informed about the study objectives and the use of the information, and they agreed to participate voluntarily.

Data was collected at two time points. The first measurement was conducted from May 12 to 16, 2025, near the end of Research Workshop I. The second was conducted from November 17 to 21, 2025, at the end of Research Workshop II.

To link the measurements, the questionnaires were matched using each student's institutional identification number. An identification code was then assigned according to the response order to organize the database and preserve confidentiality during the analysis. The records were reviewed to identify duplicate, incomplete, or unmatched responses across the two measurements. All 66 eligible students completed both questionnaires and were included in the longitudinal analysis.

Methodological Limitations

This study has several methodological limitations. The sample consisted of 66 students from only two engineering programs at a single campus, which limits the generalizability of the findings to other institutions, academic programs, or educational contexts. In addition, the assessment of generic and disciplinary competencies and academic satisfaction reflects the participants' perceptions rather than necessarily representing their actual performance.

The study employed a non-experimental longitudinal design and did not include a comparison group; therefore, the observed changes cannot be attributed exclusively to the completion of Research Workshop II. Other factors, such as accumulated academic experience, courses taken concurrently, or prior participation in research projects, may have influenced the responses. Furthermore, the sample size limits the precision of the estimates and the ability to detect small associations.

4. Results and Discussion

4.1 Wilcoxon Signed-Rank Test

The application of the Wilcoxon signed-rank test to the 38 items of the instrument, distributed across nine dimensions of generic and disciplinary competencies and one satisfaction variable, made it possible to observe the evolution of students' perceived competencies and to identify statistically significant differences in five items out of the total analyzed (13.2%), as well as one additional item located exactly at the significance threshold ($p = .050$).

The most conclusive findings correspond to the academic satisfaction variable, whose three indicators (S1, S2, and S3) showed highly significant differences ($Z = -6.085$, -5.162, and -6.148, respectively; $p = .000$ in all three cases), with an overwhelming proportion of positive ranks: between 49 and 53 students perceived greater satisfaction in Research Workshop II than in Research Workshop I, compared with only 2 to 8 cases of decrease. This result constitutes the strongest statistical evidence of the study, where the increase in satisfaction is significantly greater in T2 than in T1; this difference within the cohort should not be interpreted as a causal effect of the course sequence (Table 2).

Table 2. Satisfaction indicators.

Item	Ranges - (TII < TI)			Ranges + (TII < TI)			Emp.	Z	p (bil.)
	N	$\bar{R}$	SR	N	$\bar{R}$	SR			
S1. Satisfaction with the structure of the Research Workshop II protocol for initiating projects.	4	17.50	70.00	53	29.87	1583.00	6	-6.085	.000
S2. Satisfaction with the skills acquired through projects	8	22.81	182.50	49	30.01	1470.50	6	-5.162	.000
S3. Satisfaction with participation as a speaker	2	11.50	23.00	50	27.10	1355.00	11	-6.148	.000

Table 3 shows the area of disciplinary competencies, where only two elements reached the threshold of statistical significance: PP2 - Process and project management ($Z = -2{,}124$, $p = .034$; 36 positive ranks versus 13 negative ranks).

Table 3. Process and project management

Ítem	Ranges - (TII < TI)			Ranges + (TII > TI)			Emp.	Z	p (bil.)
	N	R̄	SR	N	R̄	SR			
PP1 · Calculate and reduce production costs of a product or process	19	23.74	451.00	24	20.63	495.00	20	-0.273	0.785
PP2 · Design production processes and developing industrial projects.	13	31.08	404.00	36	22.81	821.00	14	-2.124	0.034
PP3 · Manage process quality	15	31.80	477.00	34	22.00	748.00	14	-1.389	0.165
PP4 · I use new technologies for product design and control	16	27.25	436.00	27	18.89	510.00	20	-0.454	0.650

The development of an audit program shows Z values of -2.106, p = 0.035; 34 positive ranks versus 19 negative ranks. Both items belong to the Quality, environmental or safety management systems dimension and refer to procedural and applied competencies, which is consistent with the project-oriented training approach that characterizes Research Workshop II (Table 4).

Table 4. Quality, environmental or safety management systems.

Item	Ranges negatives (TII < TI)			Ranges positives (TII < TI)			Emp.	Z	p (bil.)
	N	R̄	SR	N	R̄	SR			
SG1 · Knowledge of industrial hygiene and safety management	16	23.03	368.50	24	18.81	451.50	23	-0.572	0.567
SG2 Propose strategies for environmental conservation	16	26.25	420.00	26	18.58	483.00	21	-0.406	0.684
SG3 Propose improvements in process and production quality management	17	26.24	446.00	28	21.04	589.00	18	-0.827	0.408
SG4 - Knowledge of national and international safety standards	16	28.16	450.50	31	21.85	677.50	16	-1.224	0.221
SG5 · Develop an audit program	19	25.37	482.00	34	27.91	949.00	10	-2.106	0.035

At the descriptive level, Operations and Logistics showed a consistent positive trend across all their items, with positive ranks exceeding negative ranks in the seven combined items, although without reaching statistical significance. In contrast, Leadership and Teamwork exhibited the only negative directional pattern in the study: across all their items, ten in total, negative ranks exceeded positive ranks. This indicates that most students perceived these competencies at similar or lower levels in Research Workshop II compared with Research Workshop I, although the differences were not statistically significant.

Table 5. Operations and logistics management.

Item	**Negative ranks** (TII < TI)			**Positive ranks** (TII < TI)			Emp.	Z	p (bil.)
	N	R̄	SR	N	R̄	SR			
GL1. Design, schedule, and control production lines or logistics processes	16	27.13	434.00	32	23.19	742.00	15	-1.611	0.107
GL2. Manage the purchasing, supplies, and supplier system	18	26.39	475.00	32	25.00	800.00	13	-1.610	0.107
GL3. Identify improvements in the storage and inventory system	19	24.89	473.00	29	24.24	703.00	15	-1.213	0.225
GL4. Identify areas for improvement in the transportation and distribution system	13	25.46	331.00	31	21.26	659.00	19	-1.961	0.050

4.2 Spearman's Rho Analysis

The results of the correlational analysis show that the satisfaction perceived by students during Research Workshop II is differentially related to the competencies evaluated. The most consistent associations were observed in dimensions linked to the practical application of knowledge, the organization of academic work, and the capacity to adapt to situations inherent to the research project process.

The dimension with the strongest overall associative strength was Technological Innovation, with a mean correlation of rho-bar = .425. All its items presented statistically significant correlations with the indicators of structural satisfaction with the protocol and satisfaction with the skills acquired, with significance values of p <= .002. The coefficients ranged from rho = .391 to rho = .449, indicating a moderate-to-high relationship between academic satisfaction and mastery of technological tools applied to industrial processes. This finding suggests that students positively value formative experiences in which they can link research with the use of technology, the design of solutions, and the improvement of production processes.

Table 6. Correlational analysis of technological innovation and satisfaction.

Item	S1 — Protocol structure		S2 — skills acquired		S3 — Academic Speaker	
	ρ	p	ρ	p	ρ	p
IT1 - Know and use technological tools or simulation programs	.449**	.000	.391**	.002	.293*	.020
IT2 - Implement technologies for process control	.428**	.000	.414**	.001	.242	.056
IT3 - Evaluate and interpret improvements derived from technological implementation	.445**	.000	.424**	.001	.231	.069

The individual coefficient with the highest value in the study was identified between item GL1 and indicator S1, with rho = .500 and p < .001. This result indicates that the ability to design, schedule, and control logistics processes is importantly related to satisfaction with the structure of the Research Workshop II Protocol. In other words, when students perceive that the research protocol is organized in a clear and sequential manner, they also recognize greater development of competencies related to the planning, control, and operation of processes. This association is consistent with the interpretation that students who perceived greater clarity in the protocol also reported stronger planning and logistics competencies.

Table 7. Operations, logistics, and satisfaction.

Item	S1 — Protocol structure		S2 — skills acquired		S3 — Academic Speaker	
	ρ	p	ρ	p	ρ	p
GL1 - Design, schedule, and control production lines or logistics processes	.500**	.000	.382**	.002	.076	.552
GL2 - Manage the purchasing, supplies, and supplier system	.318*	.011	.281*	.026	.146	.254
GL3 - Identify improvements in storage and inventories	.401**	.001	.419**	.001	.020	.875
GL4 - Manage the transportation and distribution system	.329**	.008	.313*	.013	.106	.407

For its part, the generic competency of Leadership showed the most consistent behavior in the study, reaching statistical significance in all of its indicators with satisfaction indicators S1 and S2. Within this dimension, item L4, related to decision making, presented the highest coefficient with S1, rho = .485, $p < .001$. In addition, it was the only leadership item that also correlated significantly with S3, corresponding to participation as a speaker, with rho = .287, $p = .022$. This result allows decision making to be interpreted as an articulating component among the organization of academic work, the development of skills, and students' willingness to participate in scientific dissemination activities.

Table 8. Leadership and satisfaction.

Item	S1 — Protocol structure		S2 — skills acquired		S3 — Academic Speaker	
	ρ	p	ρ	p	ρ	p
L1 - Motivation and negotiation capacity	.318*	.011	.372**	.003	.141	.272
L2 - Plan, organize, and direct work	.324**	.010	.370**	.003	.153	.231
L3 - Establish work objectives hierarchically	.395**	.001	.379**	.002	.216	.088
L4 - Make decisions responsibly	.485**	.000	.381**	.002	.287*	.022
L5 - Delegate activities to others	.316*	.012	.265*	.036	.186	.144

A particularly relevant dimension was Adaptability and satisfaction, as it was the only one that showed a cross-cutting relationship with all three satisfaction indicators. Item A2, associated with self-regulation in response to unforeseen events, and item A3, related to working under pressure, correlated significantly with S1, S2, and S3. This pattern provides evidence that adaptability is linked not only to satisfaction with the protocol structure or with the skills acquired, but also to academic participation as a speaker. In this sense, the capacity to respond to change, regulate emotions, and maintain performance under pressure appears to be a key competency for students to consider Research Workshop II as a comprehensive formative experience.

Table 9. Adaptability and satisfaction

Item	S1 — Protocol structure		S2 — skills acquired		S3 — Academic Speaker	
	ρ	p	ρ	p	ρ	p
A1 - Adapt to changes in the environment in which I operate	.356**	.004	.315*	.012	.186	.143
A2 - Self-regulate reactions to unforeseen and stressful situations	.409**	.001	.268*	.033	.262*	.038
A3 - Adapt easily to working under pressure	.369**	.003	.361**	.004	.256*	.043
A4 - Identify, transform, and innovate knowledge within the context	.332**	.008	.205	.107	.221	.082

In contrast, Management Systems was the dimension with the lowest associative strength, with a mean correlation of rho-bar = .317. This result does not imply the absence of a relationship but rather a weaker association compared with other dimensions. A possible explanation is that competencies related to standards, environmental issues, or management systems may be perceived by students as more declarative or conceptual content.

A relevant finding is the behavior of indicator S3, which refers to participation as a speaker. Significant correlations were distributed across the dimensions of Technological Innovation, Leadership, Adaptability, and Operations and Logistics Management. This behavior suggests a generalized dissociation between academic satisfaction and participation in dissemination spaces. In other words, although students may feel satisfied with the structure of the protocol and with the skills acquired, such satisfaction does not necessarily translate into participation as speakers.

The results indicate that students reported higher academic satisfaction after completing Research Workshop II, whereas the changes perceived in generic and disciplinary competencies were more selective. This pattern suggests that the second workshop was valued primarily for supporting the organization and completion of the research protocol rather than for promoting uniform development across all competency domains. This finding should not be interpreted as evidence that the course caused these changes, as the study did not include experimental assignments or a comparison group.

The increase in perceived satisfaction and the change in perceived competencies is partially consistent with longitudinal evidence linking research-based learning to improvements in methodological skills, critical interpretation of results, and research communication (Thiem et al., 2023).

However, the limited changes observed in teamwork and leadership differ from studies in which project-based engineering courses were associated with broader development of professional skills (Sperling et al., 2024). This difference may reflect the emphasis of Research Workshop II on protocol completion and the organization of individual projects rather than participation in structured collaborative activities. The findings also complement evidence from undergraduate research experiences indicating that students may value benefits related to employability and practical application differently from faculty expectations (Reisel, 2024).

Academic satisfaction was associated with several perceived competencies; however, the correlational analysis does not establish the direction of these relationships. Together, the longitudinal and correlational findings provide complementary evidence of changes over time and patterns of association at the end of Research Workshop II.

5. Conclusions

Engineering students reported greater academic satisfaction at the end of Research Workshop II. All three satisfaction questions showed statistically significant differences between the two time points. Changes in perceived competencies were limited: only the design of production processes and industrial projects (PP2) and the development of audit programs (SG5) showed significant differences, while the identification of improvements in transportation and distribution (GL4) yielded a borderline result that should be interpreted with caution.

At the end of Research Workshop II, academic satisfaction was positively associated with competencies related to technological innovation, leadership, adaptability, and operations and logistics management, among others. These associations indicate that students with a more favorable perception of their competencies also tended to express greater satisfaction, but they do not establish directionality or causality.

These results support the incorporation of specific instructional activities aimed at strengthening collaborative work, leadership, oral and written communication, and scientific dissemination. Nevertheless, the conclusions should be limited to the group studied and the institutional context. Further research involving larger samples, multiple institutions, and objective performance measures is therefore needed to determine the consistency and scope of the observed changes.

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